AD-A274 570

ATION PAGE

Form Approved
OMB No. 0704-0188

...average 1 hour per response, including the time for reviewing instructions, searching existing data sources ...ing the collection of information. Send comments regarding this burden estimate or any other aspect of this ... to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson ...of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	December 21, 1993	Semiannual Technical 01 May-31 Oct.'93

4. TITLE AND SUBTITLE

The Growth and Characterization of GaN as a Photodetector

5. FUNDING NUMBERS

G: N00014-93-1-0499
PR: s400205srr01
PE: 0603218c

6. AUTHOR(S)

Wilson Ho

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Cornell University
Department of Physics
Clark Hall
Ithaca, NY 14853-2501

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Office of Naval Research
Code 1511:EF
800 North Quincy Street
Arlington, VA 22217-5660

Code 1114SS
Max N. Yoder

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approve for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

A unique apparatus incorporating four independent supersonic jets and a substrate transfer mechanism for the growth of thin films in an ultrahigh vacuum chamber is under construction. The four jets are the continuous flow type and can be turned on and off with computer control, allowing precise control of the reactants for atomic layer epitaxy. The supersonic jet configuration prepares the reactants with high translational energies to overcome activation barriers, enhances the impinging flux, and reduces the growth temperature and by about six orders of magnitude the growth pressure. Growth of high quality films is expected. Thin films of gallium nitride (GaN) will be grown on Si(100) using triethylgallium and ammonia as the precursors. Photodetector of GaN will be fabricated at the Cornell National Nanofabrication Facility. Second harmonic generation and atomic force microscopy measurements have been performed on GaN films on sapphire grown by Asif Khan of APA Optics. A new experiment measuring the thin film interference and band gap absorption of GaN film on sapphire has been set up in the Advanced Laboratory at Cornell University.

14. SUBJECT TERMS	15. NUMBER OF PAGES
jet, beam, gallium nitride, photodetector, silicon, atomic layer epitaxy, high flux, activation energy	4
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
			UL

OFFICE OF NAVAL RESEARCH

SEMIANNUAL TECHNICAL REPORT

for

01 May 1993 through 31 October 1993

for

Contract: N00014-93-1-0499

R&T Project Code No.: s400205srr01

Scientific Officer: Max N. Yoder

Project Title: The Growth and Characterization of GaN as a Photodector

Principal Investigator: Wilson Ho

Laboratory of Atomic and Solid State Physics
Cornell University
Ithaca, New York 14853-2501

Phone Number: (607)255-3555
FAX Number: (607)255-6428
E-Mail Address: wilsonho@msc.cornell.edu

The Growth and Characterization of GaN As a Photodetector

Objectives:

This project seeks to grow GaN thin films on Si substrates prepared under ultrahigh vaccum conditions and using supersonic gas jets of triethyl gallium (TEG), $Ga(C_2H_5)_3$, and ammonia, NH_3. Fabrication of a photodetector in the photoconductive mode will be carried out at the Cornell National Nanofabrication Facility.

Progress:

This project was initiated on 01 May 1993. The design of the apparatus has been completed; the construction is currently underway. The key elements of the approach are the four independently controlled supersonic gas jets and an ultrahigh vacuum (UHV) compatible sample manipulator and transfer mechanism. Each jet is obtained by expanding the gas through an orifice into vacuum and shaped by a skimmer; it is a continuously flowing jet, as opposed to a pulsed nozzle, with the supply of gas being turned on and off. Differential pumping between the orifice and the skimmer maintains the pressure of the chamber housing the sample below 10^{-6} Torr. The UHV compatible vacuum system consists of a nozzle chamber, a growth chamber, and an interlock chamber for introducing and retrieving the substrate. A linear/rotary feedthrough transfers the substrate between the interlock and the growth chambers. The substrate can be heated up to 1200 °C for cleaning and 1100 °C for growth. Fabrication of the vacuum chambers has been completed, and the chambers have been interconnected to each other and attached to the vacuum pumps. The substrate will be heated by a BN heater up to 1100 °C during the growth. Fabrication of the substrate manipulator and transfer mechanism is scheduled for completion in January 1994. The gas handling system contains flow controllers and valves; the entire system is being welded together and is capable of delivering six different reactants. These six gas outputs are connected to the four independently controlled supersonic gas jets. Thus up to four different reactants can be beamed at the substrate in a computer controlled sequence. RHEED will be used to actively monitor the growth and to provide a feedback to control the on-off valves to the supersonic gas jets. The nozzle-skimmer housing is being constructed.

Nonlinear and linear optical second harmonic generation measurements have been performed with films grown on sapphire and supplied by Dr. Asif Khan of APA Optics. This collaboration concentrates on the study of the second harmonic generation (SHG) from films of different thicknesses with a tunable femtosecond Ti:sapphire laser. One of the most interesting observations was the dependence of the SHG signal on whether the film is n- or p-type. The SHG showed the expected dependence on the polarization and angle of incidence of the light. This work was presented by Amanda Killen at the International Conference on SiC and Related

Materials held in Washington, D.C., November 1-3, 1993. Furthermore, an analysis method has been developed for extracting the film thickness and the wavelength dependent refractive index from the linear transmission measurements. On one of the films, atomic force microscopy was performed; the image showed 0.25 μm structures on the surface of the film. In some places, jagged structures are also observed.

In the educational front, a new experiment entitled *"Thin Film Interference"* was added to the Advanced Laboratory course which I taught in the Fall semester 1993. This is the only required course for all the Physics graduate students at Cornell; it is also required for all the undergraduate majors in Physics and Applied Physics. In this experiment, the linear transmission of a 4.3 μm thick GaN on sapphire is measured and normalized to the incident beam intensity. A monochromator is used to select the wavelength from a 100 W Hg arc lamp. The incident light is chopped and the signal is detected by a lock-in amplifier. The experiment shows nicely the rapid increase in the transmission as the wavelength increases across the direct band gap and the oscillations at longer wavelengths due to thin film interference. From the data, the students extract both the thickness and the wavelength dependent index of refraction, both the real and the imaginary parts, of the GaN film.

Planned Work for Next Semiannual Period:

The construction of the entire apparatus is anticipated to be completed in February 1994. Growth of GaN on Si(100) will commence immediately. Films of 1 cm in diameter and microns in thickness are anticipated. Both sequential and simultaneous dosings of TEG and ammonia will be attempted. Substrate temperature will be systematically lowered. The grown films will be characterized by Raman spectroscopy, x-ray diffraction, x-ray photoelectron spectroscopy, and atomic force microscopy. The aim is to fabricate the first working GaN UV photodetector by the end of May 1994. Arrays of conductors will be deposited on the films. In addition to the large area detector, an imaging array will be fabricated and corresponding software programs developed.

Collaboration with Dr. Asif Khan of APA Optics is being continued. Time-resolved pump-probe measurements of the linear reflectivity, transmission, and nonlinear SHG are underway in order to measure the hot carrier relaxation times and mechanisms with 100 femtosecond time resolution. These measurements will be extended to those on AlN films and superlattices of GaN/AlN films grown on sapphire at APA Optics. Comparisons to films grown on Si by supersonic gas jets would be most illuminating.

The experiment in the Advanced Laboratory will be extended to include Raman spectroscopy for investigating the phonons of the GaN film. Ths student will be asked to identify the observed peaks and investigate the dependence of the intensity on the incident light polarization.